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4-1-2018 - Exam questions

Introduction to Nuclear Engineering (University of Dhaka)

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University of Dhaka

Department of Nuclear Engineering

B.Sc. 4th Year 1st Semester Final Examination-2018

Course Code: NE-4105

Course Title: Research Methodology, Scientific and Technical Writing

Time: 3 hours

Total Marks: 70

[Answer any five questions]

1. (a) Write down the scope of research methodology. 7
   (b) Why research methodology is necessary for the student and researcher? Explain with example. 7

2. (a) Explain how qualitative research differs from quantitative research. 5
   (b) Describe briefly about available methods for conducting quantitative and qualitative research. 9

3. (a) Distinguish among simulation, theoretical and experimental research. 6
   (b) Explain analytical and numerical solution obtained from a research. Give example with a design of reactor. 8

4. (a) Based on your proposed format, develop a case study on nuclear proliferation risk of Abdul Qader Khan. Explain the learning outcomes from your case study. 9
   (b) Write about different types of case studies. 2
   (c) What are the advantages and disadvantages of a case study research? Explain. 3

5. (a) Propose an appropriate format for evaluation of an original research article. How do you review it based on your proposed format as a reviewer? Explain each step of the evaluation report with examples. 7
   (b) How do you cite a (i) Book, (ii) Original research article, (iii) Website address, (iv) Book chapter, (v) Conference proceedings, (vi) Technical report, and (vii) Same author's multiple articles in APA referencing style in text? 7

6. (a) Explain the timeline of a research proposal and explain each step in detail with GANTT CHART to show the flexibility of timeline. 7
   (b) Mention various methods for data collection with examples. 4
   (c) Why survey is necessary for nuclear engineering? 3

7. (a) What is legal research methodology? Describe the steps in legal research. 5
   (b) What is research ethics and why is it so important? How do you write ethics in research? 6
   (c) Define research plagiarism and how can you avoid it? 3

8. (a) Describe the process of thesis writing. 7
   (b) What is a sample design? Enumerate the importance of sample design in research. 4
   (c) What is the difference between research paper and a dissertation? 3

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University of Dhaka

Department of Nuclear Engineering

B.Sc. 4th Year 1st Semester Final Examination-2018

Course Code: NE-4109

Course Title: Introduction to Nanoscience and Nanotechnology

Time: 3 hours

Total Marks: 70

Answer any five questions. Symbols carry their usual meanings

1. (a) What is nanoscale? What happens at the nanoscale? Give few examples. 3
   (b) Make a scale with examples from nanoscale to macro through microscale. 3
   (c) Who gave the first ever concept of nanotechnology? Explain Moore's law with appropriate diagram. 1+3
   (d) Define super paramagnetism. Plot M vs H/T graph and identify the ferromagnetism, paramagnetism, super-paramagnetism loop. 4

2. (a) What factors make nanomaterials differ significantly from bulk materials? 2
   (b) Schematically show how the surface area increased with the decrease of particle size. 2
   (c) What does it means the fraction of atoms at the surface? Show that fraction of atoms for Cube leads to $N^{-1/3}$ for large N, where N is the total number of atoms. Sketch the dispersion graph versus $N^{1/3}$. 2+6
   (d) Why the fractions of atoms at the surface have low coordination number? 2

3. (a) What do you understand by quantum confinement effect? Explain briefly. 4
   (b) Classify the nanomaterials based on quantum confinement. 5
   (c) Compare between 'infinite' quantum well and 'finite' quantum well behavior. 5

4. (a) What is photoresist material? How it works as positive and negative way in case of photolithography? 2+2
   (b) Schematically draw the photolithography using positive and negative photoresist. 2
   (c) Discuss the step of X-ray lithography. 4
   (d) What is soft lithography? Give a detail treatment of this process. 4

5. (a) What is homogeneous nucleation? Explain briefly. 5
   (b) Write short notes on SAMs and Sol-gel technology. 5
   (c) Differentiate between directed assembly and layer-by-layer assembly. 4

6. (a) What are the advantages of gold nanoparticles? 4
   (b) Describe Turkevich method for gold nanoparticle synthesis. 5
   (c) Describe the medical applications of gold nanoparticles. 5

7. (a) In case of Scanning Electron Microscope (SEM) and Transmission Electron Microscope (TEM), schematically show the detectable signals generated when an energetic electron beam is incident on a typical sample and the information of each signal. 5+5
   (b) Write down the essential components of SEM. 2
   (c) Why STM, SEM and TEM are operated in vacuum? 2

8. (a) What exactly is being measured in Raman spectroscopy? 2
   (b) Define Stokes line and anti-stokes line in Raman spectroscopy. 4
   (c) What is RBM mode in Raman spectra? 2
   (d) In case of Scanning electron microscope (SEM), show that the tunneling current is approximated by 6

$$I \approx \frac{4\pi e}{h} e^{-s\sqrt{\frac{8m\varphi}{\hbar^2}}} \rho_t(0) \int_{-eV}^{0} \rho_s(\epsilon)\, d\epsilon$$

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University of Dhaka
Department of Nuclear Engineering
B.Sc. 4th Year 1st Semester Final Examination-2018
Course Title: Fusion Power Engineering
Course Code: NE 4107, Credit: 3

Full Marks: 70 Time: 3 hours

Answer any five of the following questions. The marks in the margin indicate the full marks.

1. (a) Describe the key challenges to achieve a net power producing fusion reactor. 3

(b) Discuss the proton-proton cycle of fusion which operates in the sun. Why the proton-proton cycle is not suitable for replication in terrestrial fusion reactors. 3+2

(c) Calculate the total fusion energy, in Joules, residing in a liter of sea water if all the deuterons were to fuse according to the following equations. 4

$$d + d \rightarrow n + h + 3.2\ MeV$$
$$d + d \rightarrow p + t + 4.1\ MeV$$
$$d + t \rightarrow n + \alpha + 17.6\ MeV$$

(d) Methods other than heating the material have been suggested for overcoming the coulomb barrier for fusion. For example, one might consider using particles accelerators. If you were to use two of them to accelerate two beams of deuterons directly toward each other so as to collide "head on," 2

i. What voltage would each require to overcome the coulomb barrier?

2. (a) Deuteron and triton fuse to produce an alpha particle and a neutron. 2+3+2

i. Write down the nuclear equation for the reaction.

ii. Calculate the kinetic energy of each of the reaction products in MeV. Masses in u: α -particle, 4.0015; n, 1.0087; deuteron, 2.0136, triton, 3.0155. $1u = 931.5\ MeV/c^2$.

iii. Explain how the kinetic energy of both the neutron and the alpha particle can both used in a Tokamak reactor.

(b) It is thought that deuterium-tritium (D-T) fusion provides fundamentally better prospects for use in power generation than deuterium-deuterium (D-D) fusion. With the aid of a plot give two reasons why this may be the case. 4

(c) Discuss the potential advantages of a fusion reactor over a fission reactor. 3

3. (a)A plasma must be heated to a very high temperatures so that fusion can occur. Discuss the various ways how a magnetically confined plasma may be heated. 4

(b) Consider a plasma made up of equal concentrations of D and T. Let n_D and n_T represent the volume averaged number density of deuteron and triton, respectively. Both n_D and n_T can be functions of time. We have $n_D = n_T$ and $n_D + n_T = n_i = n_e$ where i stands for ions and e for electrons. Let F , L_i and B stand for particle feed rate to the plasma per unit volume, the ion loss rate per unit volume of plasma and ion burn up rate per unit volume within the plasma, respectively. 2+2+2+4

i. Write down the equation for dn_i/dt.

ii. Show that the burn up rate can be written as, $B = \frac{n_i^2}{2}\langle\sigma\vartheta\rangle$.

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iii. Define the particle (ion) confinement time τ_l as $\tau_l = n_i/L_i$. Also, define n_{DT} as $n_{DT} = n_D = n_T = n_i/2$. Show that in the steady state the fuel injection rate F is given by, $F = \frac{2\,n_{DT}}{\tau_l} + \frac{(2\,n_{DT})^2}{2}\langle\sigma\vartheta\rangle$.

iv. Define the fractional burn up as fb = B/F . Show that

$$f_b = \frac{\tau_l/\tau_{DT}}{1 + \tau_l/\tau_{DT}}$$

Where, $\tau_{DT} = 1/n_{DT}\langle\sigma\vartheta\rangle$ is the mean life of a particle (ion) between fusion events. For ignition at 10 keV with the standard plasma $n_i = 10^{20}$ m^{-3}, and $\langle\sigma\vartheta\rangle = 10^{-22}$ m^{3}s^{-3}. Assuming $\tau_l \sim 6$ s, show that $f_b \approx 0.029$, , i.e., 2.9% of the feed is burned up and rest appears as particle loss.

4. (a) For plasma fusion reactor what is the necessity to confine the plasma? 2

(b) Discuss briefly inertial confinement of plasma. 3

(c) Most research fusion reactors depend on magnetic confinement of plasma. Suppose we introduce an ion in a uniform magnetic field, created by a long cylindrical solenoid. Let $V_\parallel$ and $V_\perp$ be the components of the velocity of the ion parallel and perpendicular to the field, respectively. 3+3

i. Find the frequency of circulation of the ion around the magnetic field and describe the motion of the ion.

ii. The ion is confined in the direction transverse to the field. However, the ion will escape from the field through the end of the solenoid. Discuss how do we make a magnetic mirror so that the ion gets reflected back at the ends.

(d) Magnetic mirror is not quite suitable in confining the ions in a plasma as there is some inevitable leakage of ions through the ends. Discuss how this problem is solved in the confinement device called the Tokamak. Your discussion should include the role of the toroidal field and the poloidal field in Tokamak. 3

5.

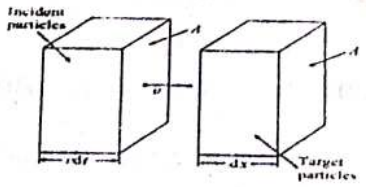

Figure shows, flux of incident particles with velocity v and number density n_2 impinging on a volume of stationary target particles of width dx and number density n_1. The macroscopic cross sectional area of both of the incident and target particles is A.

(a) Define and derive the reaction rate R_{12}. 1+2

(b) Why the first generalization of R_{12} is required? 2

(c) Establish the first generalized form of R_{12}. 2

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(d) (i)The cross section appearing in the above reaction rate equation is given by the product $P\sigma^N$. Where P is the probability of barrier penetration and σ^N is the cross section for fusion once the two nuclei come close enough to be withn the range of the nuclear force between them, given, 4+3

$$P = e^{-2G}$$

With $$2G = \frac{Z_x Z_y e^2}{4\pi\varepsilon_0}\frac{2\pi}{hv}$$

And $$\sigma^N = \frac{\pi\hbar^2}{m^2v^2}$$

Here m is the reduced mass and v is the relative velocity.

Show that ‹σv› can be written as $\langle\sigma v\rangle = \int_0^\infty e^{-(\frac{\propto}{\sqrt{E}}+\frac{E}{kT})}dE\ \frac{C}{2^{3/2}}$

Where ∝ and c are constants.

(ii) Plot the two factors in the integrand and indicate the region of E in which the integral receives the most contribution and then plot a sketch graph of ‹σv› verses T.

6. A simpler model called $0-D$ conservation of energy model is needed as an introduction to fusion energy, one that leads to an overview of the overall power balance requirements in a fusion reactor. This model can be obtained from the full set of 3-D fluid equations by making a number of simplifying assumptions and approximations. A standard 3-D fluid equation which is convenient for this purposes is given here as:

$$\frac{3}{2}\frac{\partial p}{\partial t}+\frac{3}{2}\vec{\nabla}\cdot p\vec{v}+p\vec{\nabla}\cdot\vec{v}+\vec{\nabla}\cdot\vec{q}=S$$

(a) Discuss about the importance of power balance in a fusion reactor? 2

(b) What are the assumptions and approximation that must be satisfied to obtain the 0-D model from the above 3-d equation? Hence, show that $U=\frac{3}{2}p$. Where "U" and "p" are the total internal energy density and pressure of the fuel. 4

(c) Established a steady state 0-D power balance relation in a magnetic fusion reactor from the above 3-D equation. 6

(d) Define the following terms: Ideal ignition and Ignition condition. 2

7. (a) What are the functions of the fusion reactor blanket? 2.5

(b) Define neutron wall loading (Λ_n). What is the significant of Λ_n? Why the scientists neglect the effect of Λ_n in inertia confinement of fusion? 1+1.5+1.5

(c) Suppose, a plasma ion of mass m_1 and velocity v_1 enters the first-wall and collides elastically with a stationary atom of mass m_2. If the maximum energy transfer from incident particle to stationary wall material is $(\Delta E)_{max}$ and the kinetic energy of the incident ion is $(E)_{inc}$. Then prove that, 4

$$(\Delta E)_{max}=\frac{4m_1m_2}{(m_1+m_2)^2}E_{inc}$$

(d) How impurities are produced in plasma? How the impurities degrade the energy viability of the fusion reaction chain? 3.5

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8. A generic magnetic fusion reactor is illustrated in the following figure. The plasma radius "a" and coil thickness "c" are determined by the simultaneous consideration of two major design issues: minimizing the cost and satisfying magnet stress limitations.

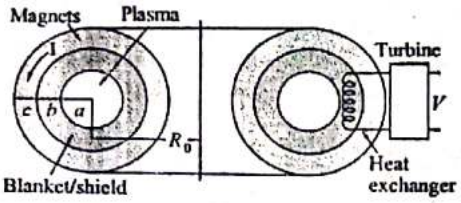

Figure: Generic toroidal fusion reactor showing the plasma, blanket-and-shield, and magnets.

(a) Discuss how the cost of a nuclear fusion reactor is calculated. 2

(b) To minimize the cost is equivalent to minimizing the engineered volume (V_l) of material required to produce a given electrical power output (P_E). Show that, for $\eta_t = 0.4$, $E_n = 14.1$, $E_\alpha = 3.5\ MeV, E_{Li} = 4.8\ MeV$ the ratio of V_l and P_E can be written as: 6

$$\frac{V_l}{P_E} = 0.79\ \frac{(a+b+c)^2 - a^2}{aP_W}$$

(c) Assume that maximum allowable constraint value $B_c = B_{max} = 13\ T, b = 1.2, \sigma_{max} = 300\ MPa \approx 3000\ atm$ and $P_W = 4\ ^{MW}/_{m^2}$. Find out the optimum value of "a", "c" and $\frac{V_l}{P_E}$ from the following equations. 3+1+2

$$\frac{V_l}{P_E} = \frac{0.79}{P_W(1-\xi)^2}\left[(4\xi)a + (1+\xi)^2\frac{b^2}{a} + 2(1+\xi)^2 b\right],\ c = \frac{2\xi}{1-\xi}(a+b)$$

Here, $\xi = \frac{B_c^2}{4\mu_0\sigma_{max}}$.

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University of Dhaka

Department of Nuclear Engineering

B.Sc. 4th Year 1st Semester Final Examination-2018

Course Code: NE-4101

Course Title: Environment and Nuclear Disaster Management **Time: 3 hours**

(Answer any five of the following questions) **Total Marks: 70**

1. (a) What do you mean by radiological monitoring of the environment? 01
   (b) Discuss in brief about the sources of natural radiation and artificial radiation. 04
   (c) Do you think that environmental radioactivity monitoring is needed? Why? 03
   (d) What are the objectives of radiological monitoring of the environment? Discuss in brief. 04
   (e) How is radioactivity monitored? 02

2. (a) Explain deposition velocity and bioaccumulation factor for radiological dispersion. 02
   (b) Explain principal exposure pathways to humans for radioactive gaseous effluents from nuclear power plant. 04
   (c) 04

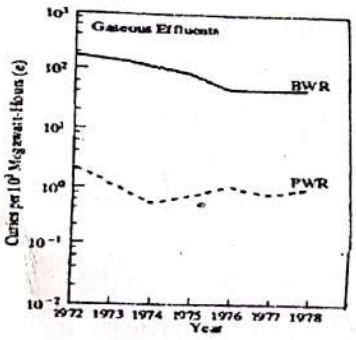

Figure shows the activity concentrations in the gaseous effluents of two different reactors.

   (i) Explain why is the activity of *BWR* effluents much higher than that of *PWR*.
   (ii) What are the sources of gaseous radioactive effluents of *PWR*.

   (d) The maximum probable consumption rates of seafood from the (brackish) waters near a *BWR* plant are determined to be: fish, 110 g/day; mollusks, 10 g/day; and crustacea, 10 g/day. The plant discharges 0.197 μCi of ^{59}Fe per year, and the dilution factor at a point 30 ft from the exit pipe is $6.29 \times 10^{-16}\ yr/cm^3$. The $(MPC)_w$ for ^{59}Fe is $6 \times 10^{-5} \mu Ci/cm^3$, based on exposure to the gastrointestinal (GI) tract. The saltwater concentration factor of fish for iron is 1,800. Estimate the yearly dose to the GI tract from sea fish. 04

3. (a) Cite some area radiation monitoring equipments. 02
   (b) Explain in a flow chart how the liquid wastes are managed in pressurized water reactor. 04
   (c) What are the specific objectives of source monitoring during the operational stage of nuclear power plant? 04

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(d) In an accident in a 1,000 MW reactor, $6.25 \times 10^6 Ci$ of ^{135}I (25% of its equilibrium activity) is released into the containment building, which leaks at the rate of 0.1 % per day. Calculate the total external gamma-ray dose for a person during the first 2 hrs after the accident who is standing at a distance of 2,000 m from the reactor building. ^{131}I is assumed to be released at ground level, under type F dispersion conditions and with a wind speed of 1 m/sec. Given that $\lambda_{I-135} = 9.98 \times 10^{-7}\ sec^{-1}$, $\sigma_y = 70\ m$, $\sigma_z = 21\ m$, $\bar{E}_\gamma = 0.371\ MeV$, $C_0 = 3.25 \times 10^6$. 04

4. (a) What are the general responsibilities of the operators for monitoring a nuclear facility? 03

(b) Do you have any idea about 'Source Monitoring' and 'Environment Monitoring'? Discuss in brief. 03

(c) What are the general responsibilities of the regulatory body for monitoring a nuclear facility? 03

(d) What do you understand by the Environmental, Population and Economic Characteristics in case of nuclear radiation monitoring? 02

(e) Write down the characteristics on which the programmes of radiation monitoring depend. 03

5. (a) Why Emergency Management System is necessary for a nuclear power plant? Discuss in brief. 03

(b) What should be included in Emergency management system for NPP? 04

(c) What are the Fundamental safety principles in case of radiation protection? Discuss in brief. 04

(d) What measures have been taken to ensure that the likelihood of an accident having harmful consequences is extremely low? 03

6. (a) Which conditions should be taken into account in the design of any nuclear or radiological monitoring programme? 02

(b) Describe shortly different types of monitoring for radiation protection. 03

(c) Discuss about sample collection, handling, preparation and transport for a sampling and analysis of waters, waste waters, soils and wastes of a nuclear or radiological facility. 04

(d) A BWR plant emits an average of 1.23 Ci of ^{131}I per year from a vent 30 m above ground level. Assuming type –E stability conditions and average wind speed of 1.2 m/s, calculate- 05

(i) the equilibrium dose to an adult thyroid at a point on the ground 2000 m from the plant;

(ii) the annual dose to the thyroid at this point.

[For ^{131}I, $T_{1/2} = 8.04\ days$, $T_{(1/2)b} = 138\ days$, Effective energy equivalent, $\xi = 0.23\ MeV$ and fraction of the radionuclide, $q = 0.23$. The mass of an adult thyroid is 20 g. For E-type conditions, $\chi\vartheta/Q = 6 \times 10^{-5}\ m^2$ at 2000 m]

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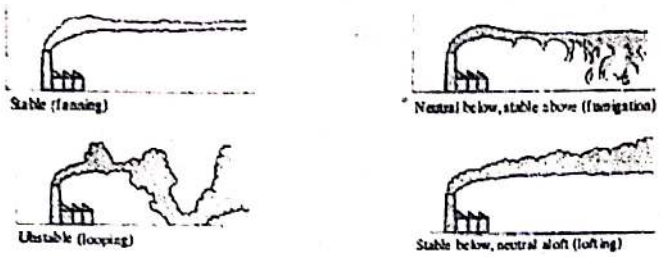
7. (a) Explain the terms plume rise, dry deposition and wet deposition. 02

(b) Cite Pasquill atmospheric conditions for dispersion coefficient calculation? Draw the vertical dispersion coefficient (σ_z) as function of distance from the source under all conditions. 04

(c) Figure shows typical smoke plumes emitted under the different temperature conditions observed in the atmosphere. Draw the adiabatic lapse rate and the actual temperature profiles with respect to altitude. 04



(d) A 1,000 MWe plant operates at an efficiency of 38% on 13,000 Btu/lb coal with a 9% ash content. The plant stack is 100 m high. 04

i. Estimate the activity of $^{226}_{88}$Ra emitted from the plant if 2.5% of the ash escape from the stack.

ii. Compare the maximum concentration of $^{226}_{88}$Ra at ground level under $Pasquill\ F$, 1 m/sec dispersion conditions with the $(MPC)_a$ for this nuclide of $3 \times 10^{-12}\ \mu Ci/cm^3$

Dilution factor = $2.5 \times 10^{-6} sec/m^3$ $\quad$ $1\ MW.hr = 3.142 \times 10^6 Btu$

8. (a) Write down the concept and types of risk. 03

(b) What are steps of the risk management process? Discuss in brief. 04

(c) Discuss in brief about 'Environmental risk assessment methodology'. 04

(d) Develop a fault tree for determining the probability of a loss of power to engineered safety features of a nuclear power plant. 03

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University of Dhaka

Department of Nuclear Engineering

B.Sc. 4th Year 1st Semester Final Examination-2018

Course Title: Nuclear Power Plant Design and Features

Full Marks: 70 Course Code: NE-4103

Total Time: 3 hours

Answer any five of the following questions

1. a) Cite some typical nuclear reactor core design variables. 3

b) Describe the design principles and examples of limits for the following items of *Pressurized Water Reactor (PWR)* fuel assembly design. 3

Fuel Assembly Width Fuel Rod Pitch Fuel Assembly Height

c) Consider a cylindrical nuclear power reactor of core height H and core thermal power $Q\ MW$. The reactor has a total of N fuel rods arranged in square assembly with lattice pitch P. Prove that the minimum diameter of the core is given by 4

$$D_{c,min} = 2P\sqrt{\frac{QF_N^q}{\pi H q'_{max}}}$$

Where, F_N^q = nuclear hot channel factor, and q'_{max} = maximum linear power density

d) A bare reactor consists of long rods of natural uranium metal, 25.4 mm in diameter, arranged in square lattice with a pitch of 0.152 m, suspended in a cylindrical vessel containing heavy water as moderator; the ratio of the height to the diameter of the core is 1.2. 4

i. Estimate the critical height and radius of the reactor.

ii. Determine the mass of natural uranium that will make the reactor just critical.

Material buckling, $B_m^2 = 8.60\ m^{-2}$;

Density of uranium metal, $\rho_u = 19.0 \times 10^3\ kg/m^3$

2. a) Fission products and neutrons are two of energetic particles produced as a result of the fission process. Discuss the interactions of these two different particles with the fuel (fission product) and the fuel cladding and structural materials (neutrons) for all reactor types that can be covered as a single answer. 5

b) Discuss the effect of irradiation time on radiation damage imposed upon 3

i) fuel element cladding, and *ii)* pressure vessels of light water reactors.

c) Irradiation induced swelling is an important phenomena for materials performance in a neutron environment. Discuss the important variables that determine a material's susceptibility to swelling. 3

d) Stress corrosion cracking (SCC) is one of the most important environmental degradation phenomena for LWR systems. List and discuss the key factors involved in the SCC process. Include the effect of radiation. 3

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3. a) Explain challenges and measures in core design for high burnup based on the transition of design specifications of *PWR* fuel assembly. 4

b) Cite different cost components of nuclear power plant. Consider a *PWR* based nuclear plant with net 1200 *MW* electric power output, operating at 90% capacity factor. If the plant has a thermal efficiency of 34%, calculate the total electricity generation cost in $/kWh from the following data. 3

Avg. fuel assembly burnup = 50 *GWD/THM* Weight of an assembly= 450 *kg*

Costs of an assembly = 1.3×10^6 O & M costs = $100,000,000/yr

Amortized capital costs = $277,000,000/yr Tax for disposal of the used fuel = 0.1 *cent per kWh*

c) Consider three nuclear power reactors NPR_1, NPR_2 *and* NPR_3 reflected by *light water*, *heavy water* and *graphite* respectively. If all these reflectors are of same thickness (80 *cm*), then rank the reactors mentioned above according to the efficiency of the reflector. 3

Material	H_2O	D_2O	C
Diffusion Length (cm)	2.54	160	53.5

d) Define reflector savings. Calculate the critical core radius and critical mass of a spherical reactor, moderated and reflected by unit density water. The core contains ^{235}U at a concentration of $0.0145\ g/cm^3$. The required data are given below. 4

Geometrical buckling, $B_g = 0.0529\ cm^{-1}$ Migration area, $M_T^2 = 30.8\ cm^2$

4. a) Describe the main components of a *PWR* main coolant pump (*MCP*). 4

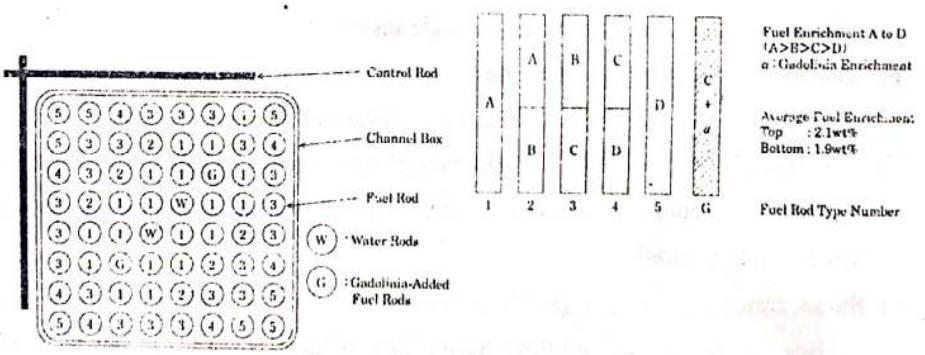
b) Consider the startup of a *PWR* from cold zero power to hot full power after refueling. 4

i. Describe different methods available for plant heatup.

ii. Why is the heatup by fission reaction prohibited?

iii. Is reload startup physics test mandatory? Explain.

c) Figure shows a two region fuel assembly of *BWR* in which enrichment is varied axially. Draw and explain the variation of core power distribution with respect to height of the core. 3


Control Rod
Channel Box
Fuel Rod
W : Water Rods
G : Gadolinia-Added Fuel Rods
Fuel Enrichment A to D (A>B>C>D)
a : Gadolinia Enrichment
Average Fuel Enrichment: Top : 2.1wt% Bottom : 1.9wt%
Fuel Rod Type Number

d) Estimate the pumping power required to pump the cooling water through the core of a *PWR* when operating at 3800 MW_t. Average coolant temperature at the operating power is 311 ^0C. Use the following data: 3

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Pressure drop due to friction along the fuel rods = $6.0 \times 10^4 Pa$

Pressure drop due to spacer grids = $6.5 \times 10^4 Pa$

Pressure drop due to entrance and exit effects = $1.5 \times 10^4 Pa$

Mass flow rate = $1.83 \times 10^4\ kg/s$

Density of water, $\rho_w^{311} = 691\ kg/m^3$

5. The schematic drawing of a draft cooling tower used in a large *LWR* plant is shown in *Figure 1*. Hot water from the condenser enters the tower at *Point* 1, at a flow rate $\dot{m}_{w1}$ = 17,000 kg/s, temperature T_1 = 35°C and enthalpy h_1 = 146.7 kJ/kg, and is sprayed downward to be cooled by a flow of cold air. The water collected at the bottom of the tower (Point 3) is returned to the condenser. Air entering the tower at Point 2 is perfectly dry ($\emptyset_2$= 0) at temperature T_2 = 20°C, and with a flow rate $\dot{m}_a$= =16,000 kg/s. The air exiting the tower at Point 4 is at T_4 = 30°C, with 100% humidity ($\emptyset_4$ = 1). The pressure can be assumed atmospheric throughout the system.

(i) Find the mass flow rate of water discharged from the cooling tower, $\dot{m}_3$ (Hint: the air and the water in the air at Point 4 have the same volumetric flow rate, m^3/s] 4

(ii) Find the temperature of water discharged from the cooling tower, T_3. 6

Now consider a different situation: it is a very hot day, and the air entering the cooling tower is at the same temperature of the water entering the cooling tower, i.e. $T_2 = T_1$.

(iii) Will T_3 be higher, lower or equal than T_1? In other words, will the cooling tower still be able to cool the water coming from the condenser? 2

[A qualitative answer is acceptable]

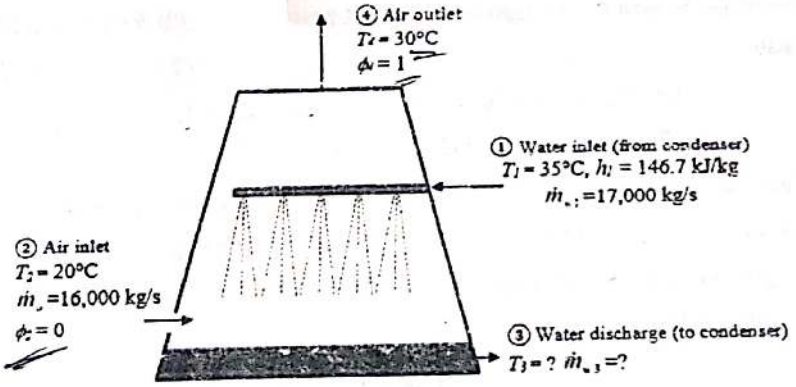

Figure 1. Draft cooling tower

Assumptions:

- Assume steady operation
- Neglect kinetic and gravitational terms in the energy equation
- Neglect solubility of air in water
- Treat air as an ideal gas (R = 287 J/kg-K; C_p = 1005 J/kg-K)
- You may treat subcooled water as an incompressible fluid (ρ=1000 kg/m³, Cp=4180 J/kg-K)

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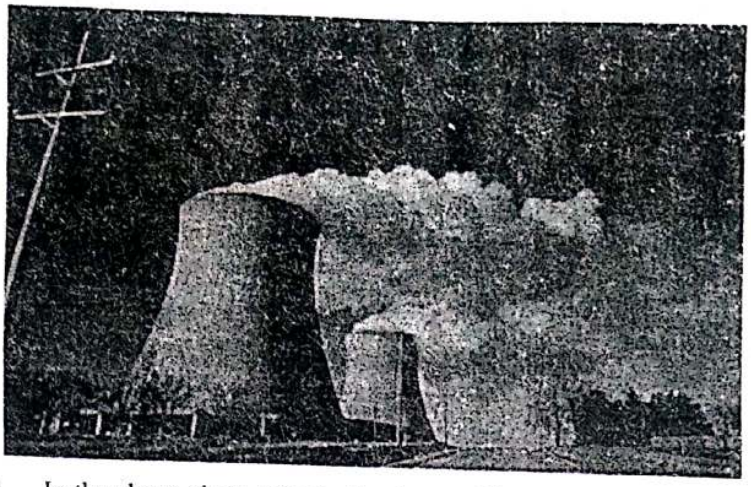
Properties of saturated water:

Temperature (°C)	Pressure (kPa)	ρ_f (kg/m³)	ρ_g (kg/m³)	h_f (kJ/kg)	h_g (kJ/kg)
30	4.24	995	0.03	126	2556
100	101 (atmospheric)	958	0.6	419	2676



(iv) In the above photo, why is the plume of humid air at the top of the tower visible?

6. a) Explain following cooling tower parameters: 3

Blowdown, Cycle of Concentration (C.O.C), Makeup

Also, Prove that $Blowdown = \frac{Evaporation}{C.O.C-1}$

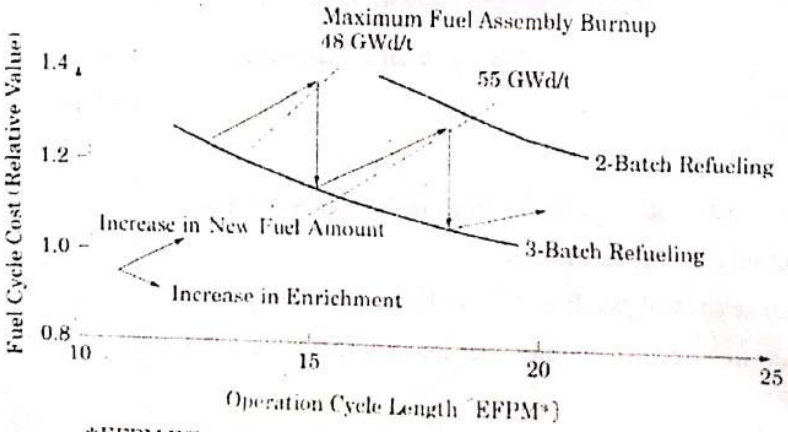
b) Describe the cooling of a typical pressurized water reactor (*PWR*) for the following states 4

i. Cooldown to Hot Standby Mode

ii. Cooldown to Cold Shutdown Mode

c) What are the functions of the *BWR* reactor core isolation cooling system? Describe standby liquid control system of *BWR* with proper diagram. 4

d) Figure shows the relationships for cycle length, batch size, maximum fuel assembly burnup, and fuel cycle cost. 3



*EFPM:Effective Full Power Month

Disscus possible ways to minimize the fuel cycle cost.

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7. a) What are the differences between emergency shutdown and gradual shutdown of a reactor? 2

b) Draw and explain the chemical and volume control system of a typical PWR. How it
   i. Purifies the reactor coolant . 4
   ii. Changes the core reactivity
   iii. Maintains the level of pressurizer at the desired set point.

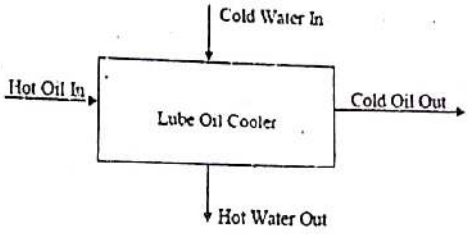
c) How does emergency core cooling system of BWR perform core cooling during LOCA? 4

d) What are the major steps in BWR startup? Discuss in brief. 4

8. a) Describe the main functions of the following components of turbine oiling system of nuclear power plant. 3

   Main Oil Pump Auxiliary Oil Pump Jacking Oil Pump

b) A typical turbine lube cooler is shown in the following figure. Draw a temperature control circuit and explain how it maintains the lube oil temperature to the set point. 4



c) Explain with proper diagram how the following transformers supply electrical power to low and high voltage equipment in a nuclear power plant both in normal operation and plant outages. 4

   Unit Transformer Auxiliary Transformer Station Transformer

d) A 1200 MW_e *VVER* based nuclear power plant uses a 2 *pole* electrical generator with an output voltage of 24 kV synchronized with a running network of frequency 50 Hz. 3

   i. Calculate the turbine rpm if the plant is operating at its rated capacity.

   ii. Due to decrease in electrical demand, the plant is now operating at 1000 MW_e . How can you keep the rpm constant calculated in part *i*?

[The End]

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